TOSHIBA
Leading Innovation

Perspective of Accelerator Technology in Toshiba

Dec.12,2017

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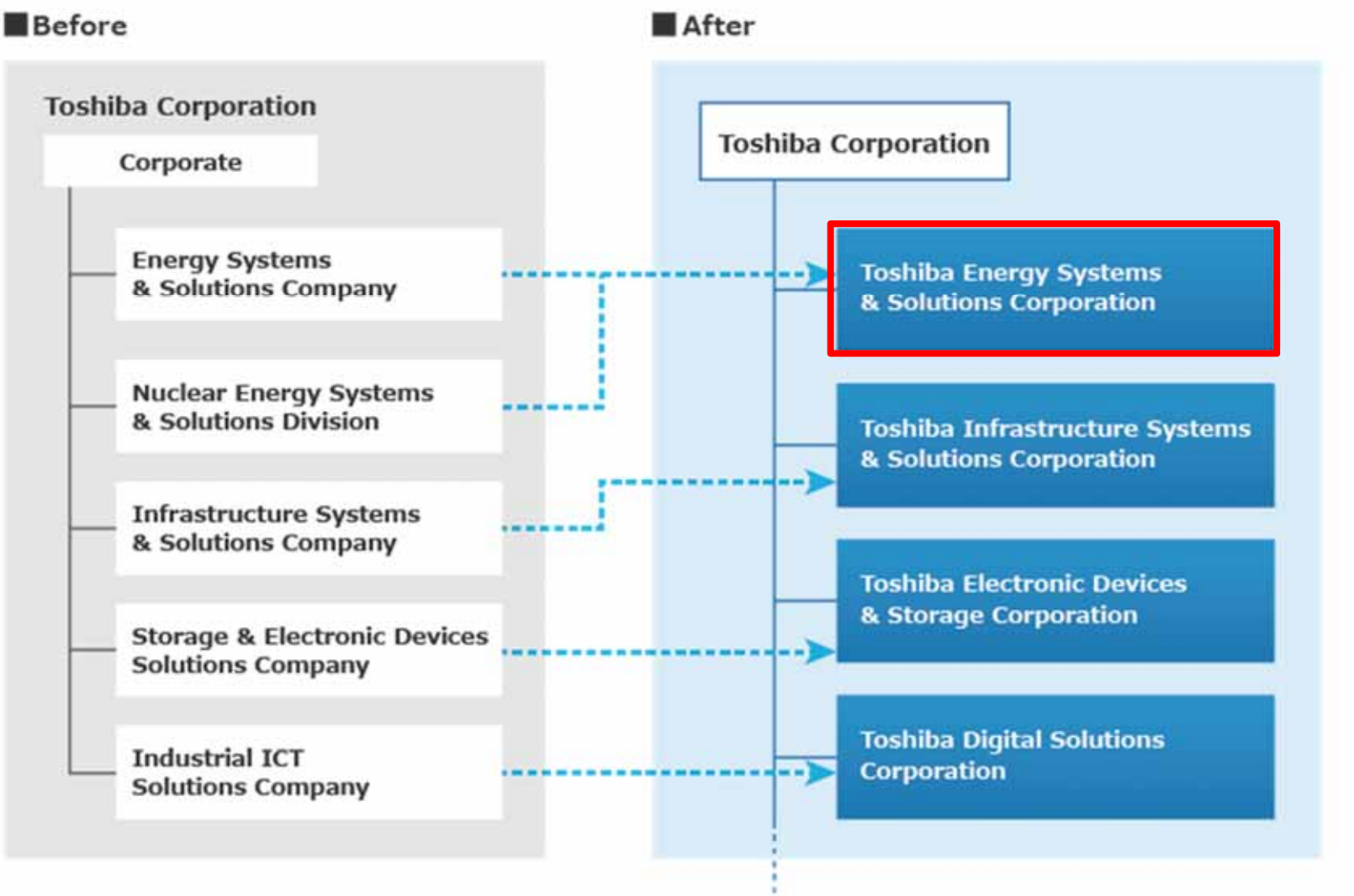


Toshiba New Business Structure

TOSHIBA
Leading Innovation

TOSHIBA ENERGY SYSTEMS & SOLUTIONS CORPORATION

Introduction

Energy for Sustainable Life

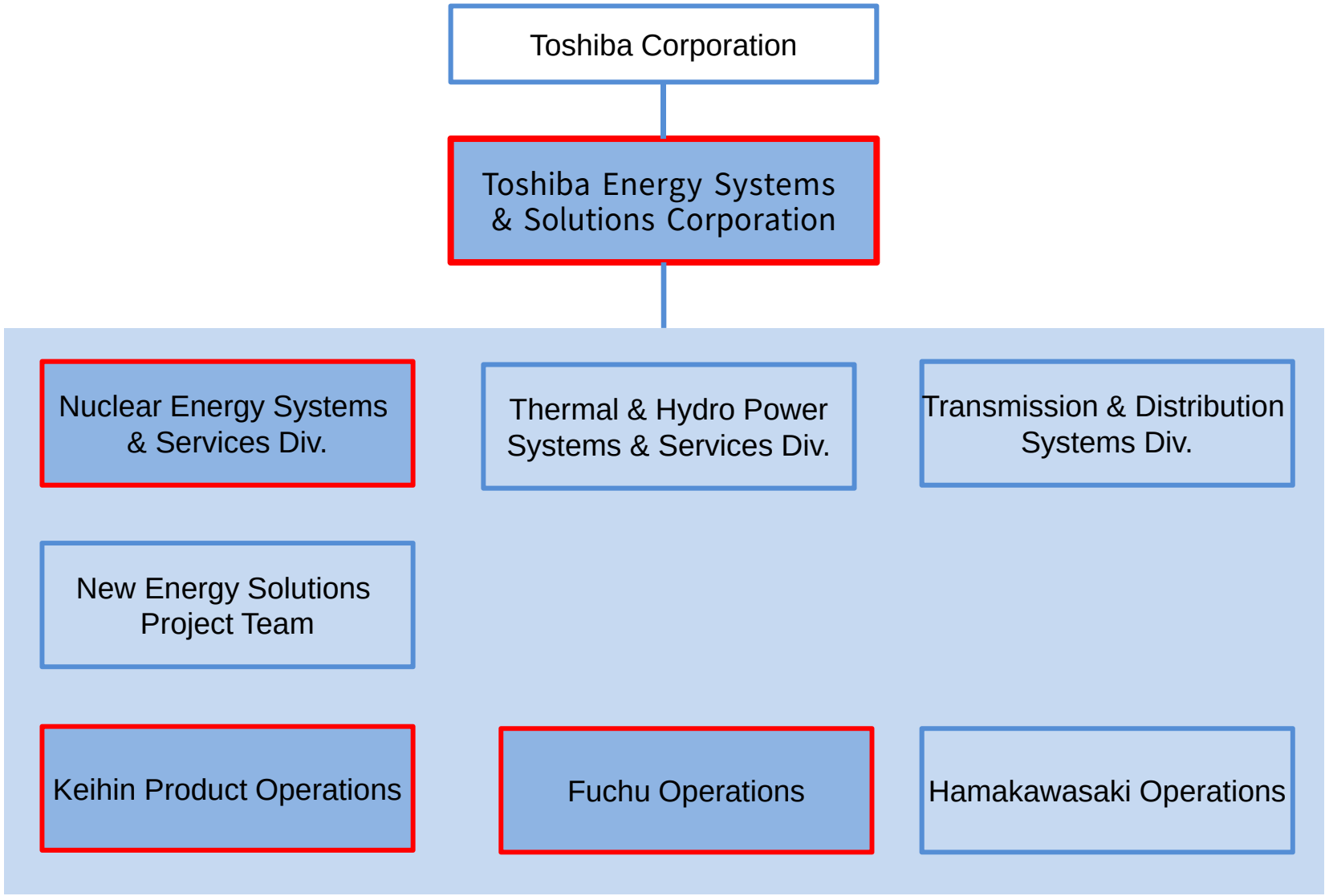
Company Outline

Introduction

Company Name	Toshiba Energy Systems & Solutions Corporation
Headquaters	Address：72-34, Horikawa-cho, Saiwai-ku, Kawasaki-shi, Kanagawa
Date of Succession	October 1, 2017 (Split off from Toshiba Corporation)
President and CEO	Yoshihiro Aburatani
Common Stock	¥10 billion
Business Outline	Development, manufacture and sales of energy business products, systems and services
Net Sales	¥974.9 billion (Consolidated net sales of Toshiba group, energy business , FY2016)
Number of Employees	Approx. 7,200 (as of 1st Oct, 2017)

Organization

Introduction



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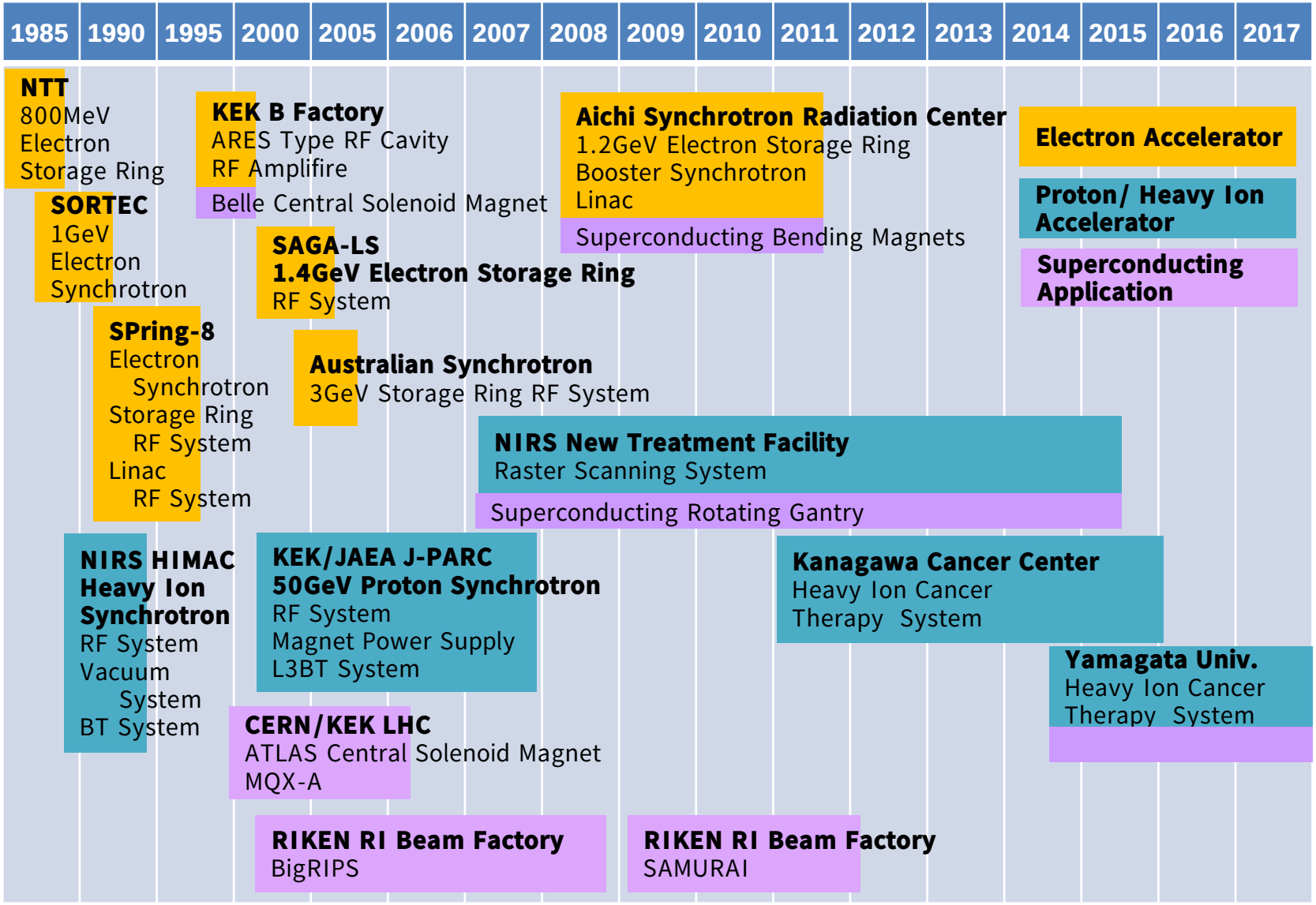
TOSHIBA Experiences of Accelerator

Experience



Accelerator System

Experience

- **1950~1960**
  - Cyclotron（Tokyo University, RIKEN）
- **1980~1990**
  - RFQ for heavy Ion accelerator, Ferrite Loaded RF Cavity, Vacuum duct（Tokyo University）
  - Electron Acceleration & Storage Ring for Semiconductor Lithography（NTT）
    - Circumference：53m
    - Energy：13Mev~800MeV
    - Stored Current：120mA
  - Electron Synchrotron for Semiconductor Lithography (SORTEC)
    - Circumference：43m
    - Energy：40MeV~1GeV
    - Beam Current：70mA
    - Donated to Kingdom of Thailand since 1996.

Accelerator System

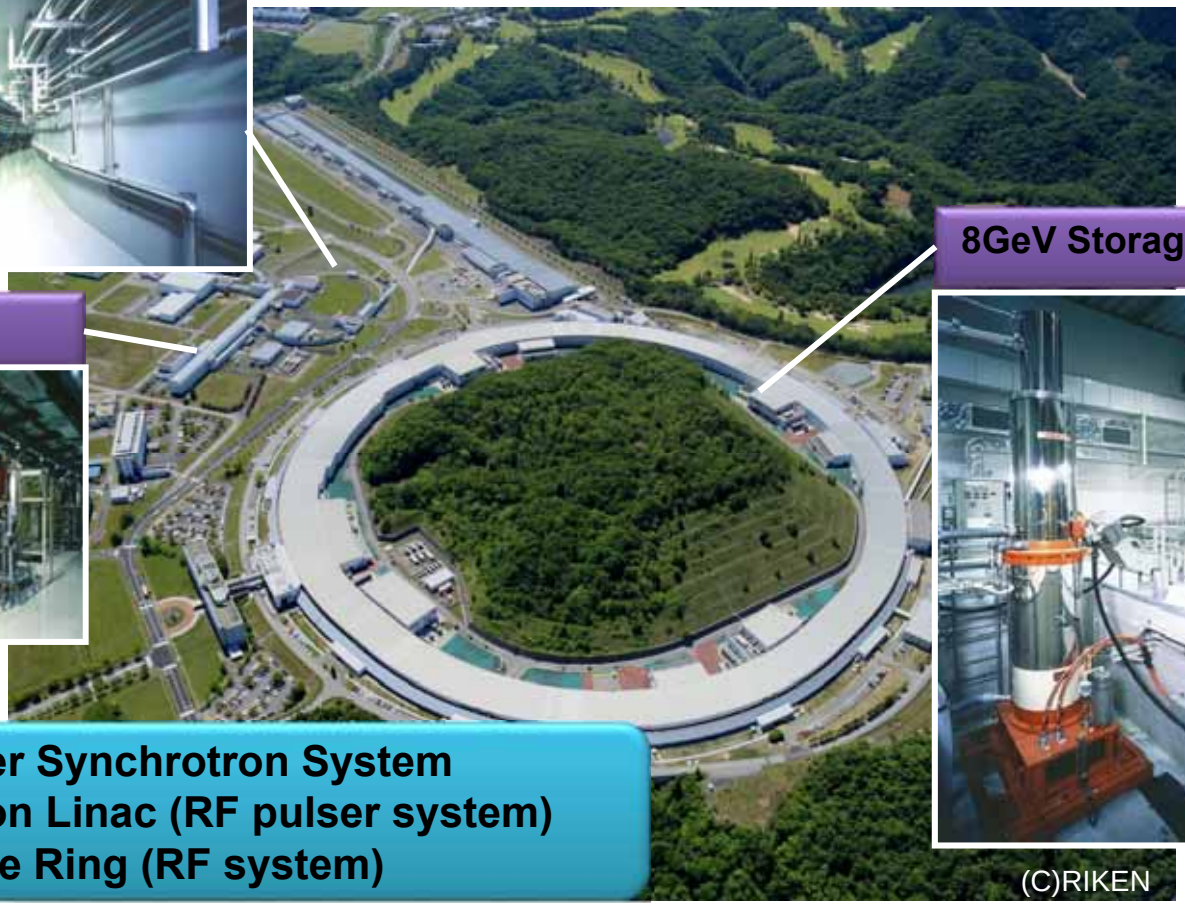
Super Photon ring-8 GeV (SPring-8)

Experience

Customer ：JAERI/RIKEN
Public use since 1997

8GeV Booster Synchrotron

1GeV Linac



8GeV Storage Ring

(C)RIKEN

- 8GeV Booster Synchrotron System
- 1GeV Electron Linac (RF pulser system)
- 8GeV Storage Ring (RF system)

Synchrotron System

SPring-8 Booster Synchrotron

Experience

■Main Parameter：
- Injection Energy 1GeV
- Maximum Energy 8GeV
- Circumference 396.12m

■Cavity:
- 5-cell Cavity × 8
- 250kW/cavity

■Klystron:
- E3732 ×2
- Frequency 508.58 MHz
- Max. Output 1 MW(CW)

Storage Ring RF System

SPring-8 RF System for Storage Ring

Experience

Cavity:
- Single Cell × 8×4stations
- Input Power 150kW

Klystron:
- E3732
- Frequency 508.58 MHz
- Max. Output 1 MW(CW)

Storage Ring RF System

Australian Synchrotron RF System

Experience

RF Power Supply & Klystron

RF Cavity

Customer ：Major Project Victoria
Operation since 2006

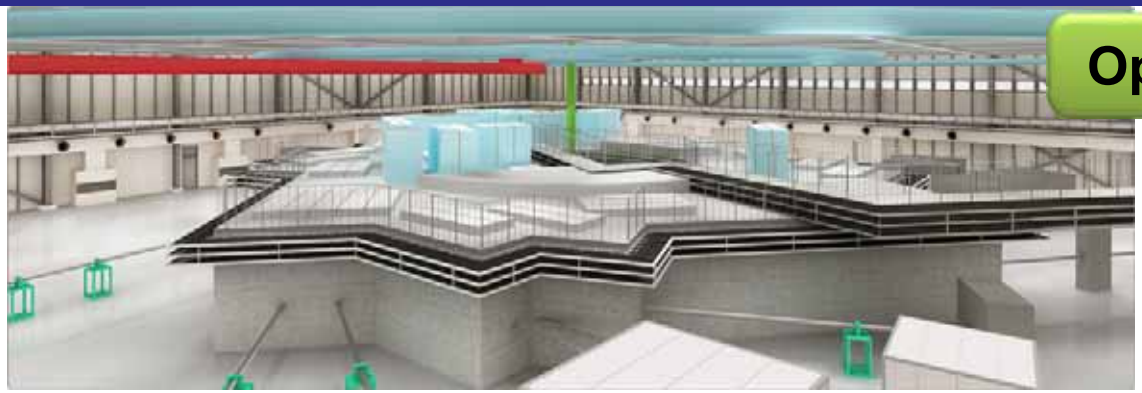
Main Parameter

- Frequency 499.654MHz
- Max. Voltage 750kV/cavity
- HOM Damped Cavity
- Klystron E3774U (Efficiency >60%)

Synchrotron Radiation Facility

Aichi Synchrotron Radiation Center

Experience



Operation since 2012

(C)Aichi Synchrotron Radiation Center

Injector Linac

Superconducting Bending Magnet

Storage Ring RF Cavity

Injector Linac
- Electron energy 50MeV
- RF frequency 2856MHz

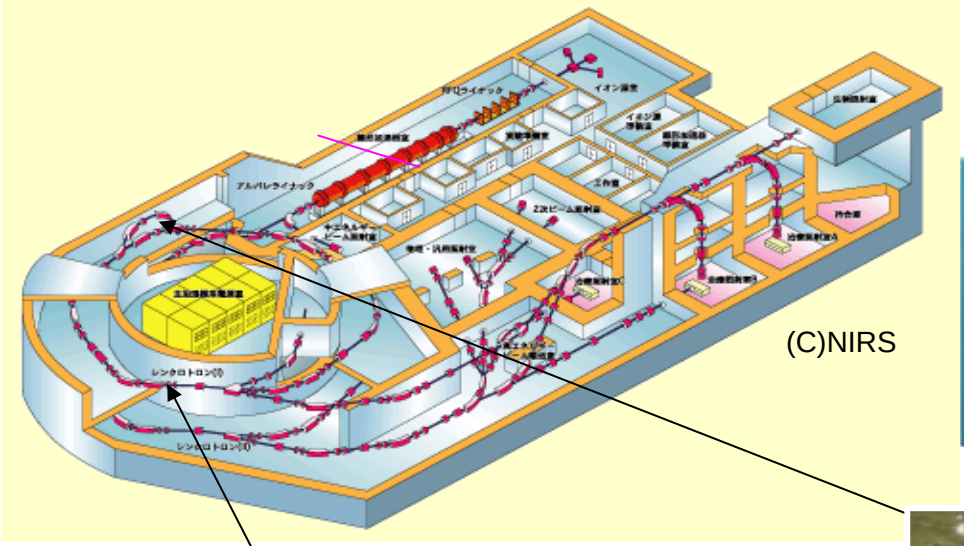
Booster Synchrotron
- Electron energy 1.2GeV
- Circumference 49.2m
- Repetition rate 1Hz

Storage Ring
- Electron energy 1.2GeV
- Circumference 72m
- Current 300mA
- Emittance 50nmrad

Heavy Ion Synchrotron

Contribution to Building HIMAC Synchrotron

Experience



Operation since 1994

- RF Cavity
- Vacuum System
- Beam Transport Line

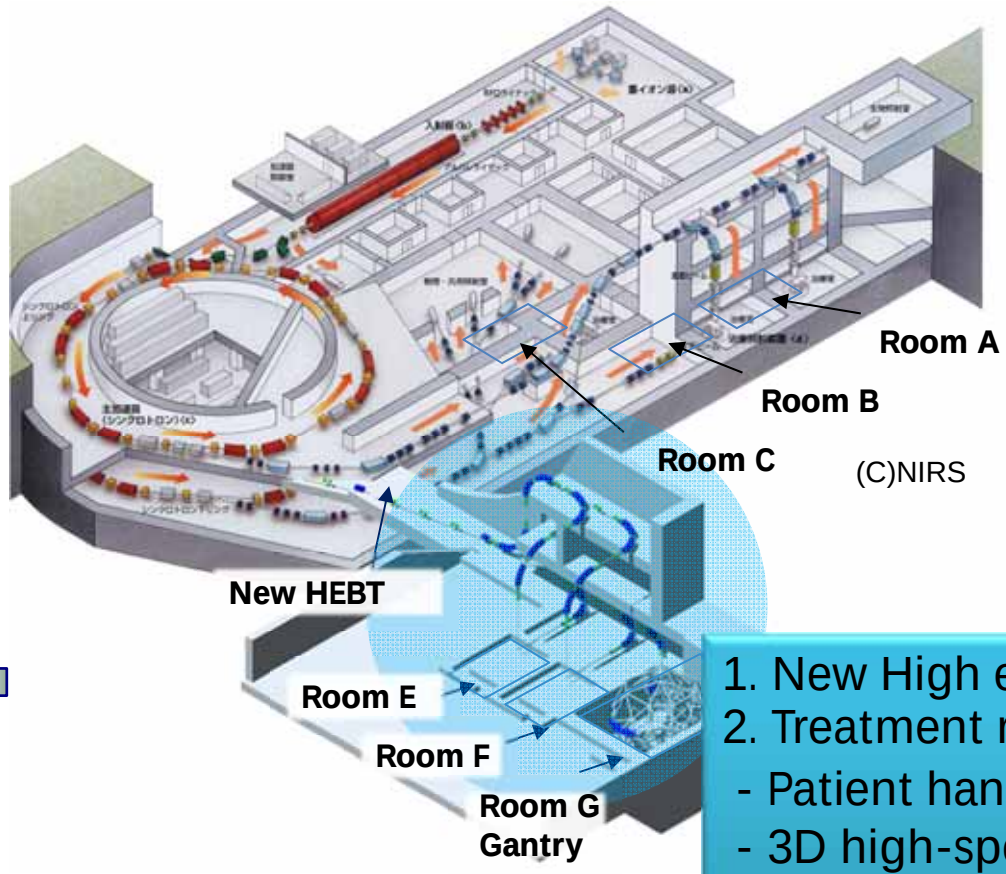
Ferrite Loaded RF Cavity

Injection Beam Transport Line

Heavy Ion Cancer Therapy System

Contribution to Building New Treatment Facility

Experience



(C)NIRS

Treatment Room

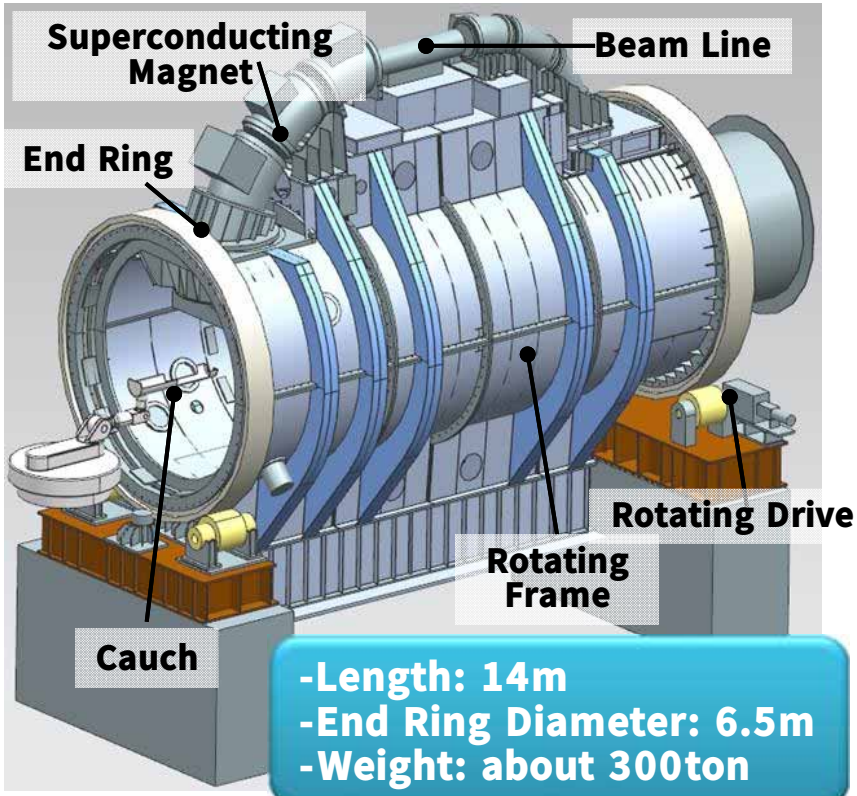
1. New High energy beam transfer line (HEBT)
2. Treatment rooms E & F **(Operating in 2011)**
   - Patient handling system with robot-arm bed
   - 3D high-speed scanning irradiation system
   - Treatment management for particle therapy
3. Treatment room G **(Operating in 2015)**
   - Superconducting rotating gantry

Superconducting Magnet System

Superconducting Rotating Gantry for NIRS

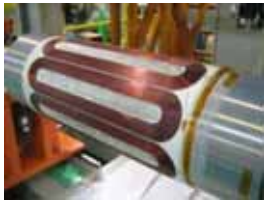
Experience

This isocentric rotating gantry can transport carbon ions with the maximum energy of 430MeV/u to an isocenter with irradiation angles of over +/-180 degrees.



-Length: 14m
-End Ring Diameter: 6.5m
-Weight: about 300ton

Treatment Room G



Multipole Coil

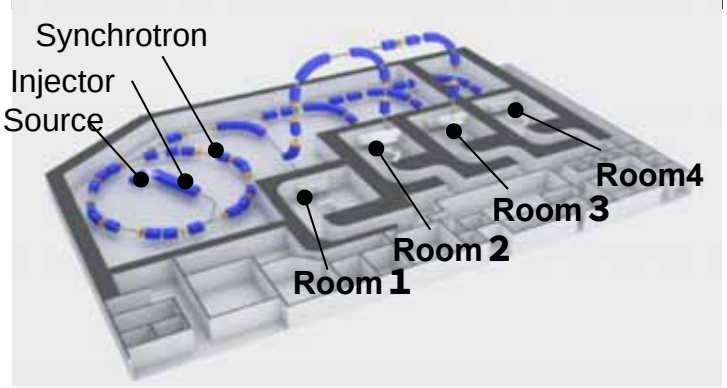
Bending Coil

Heavy Ion Cancer Therapy System

Kanagawa Cancer Center i-ROCK

Experience

- "i-ROCK" is TOSHIBA's 1st machine to the market based on NIRS technologies.
- The treatment stared since 2015.

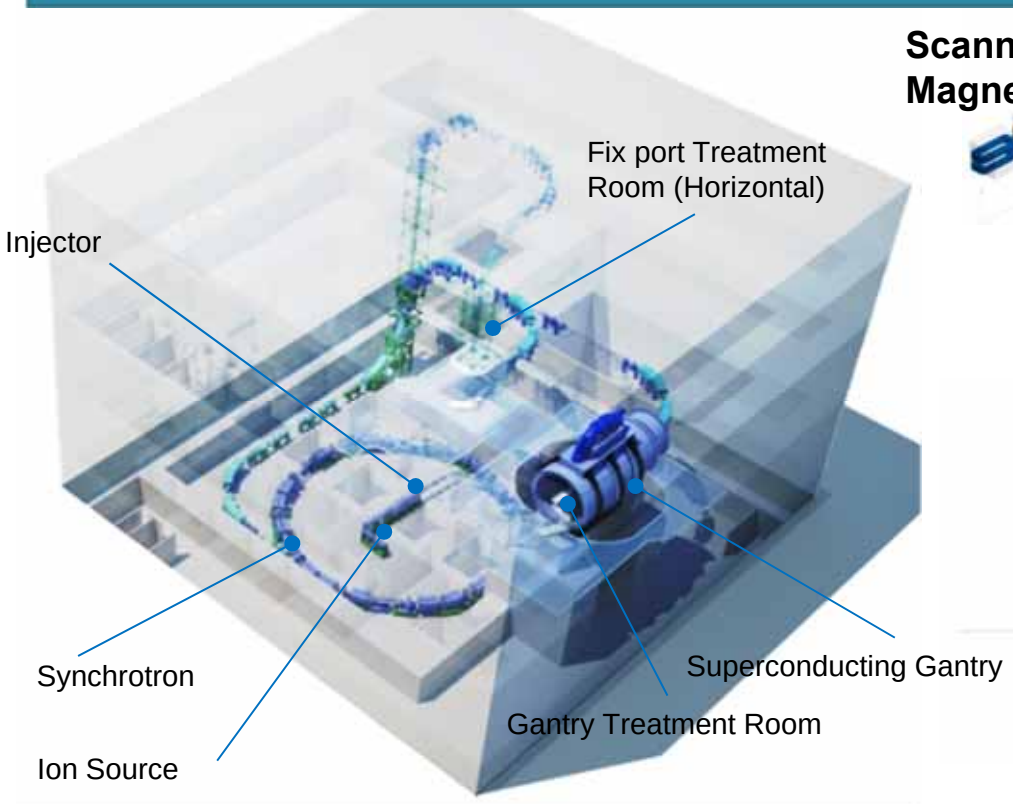


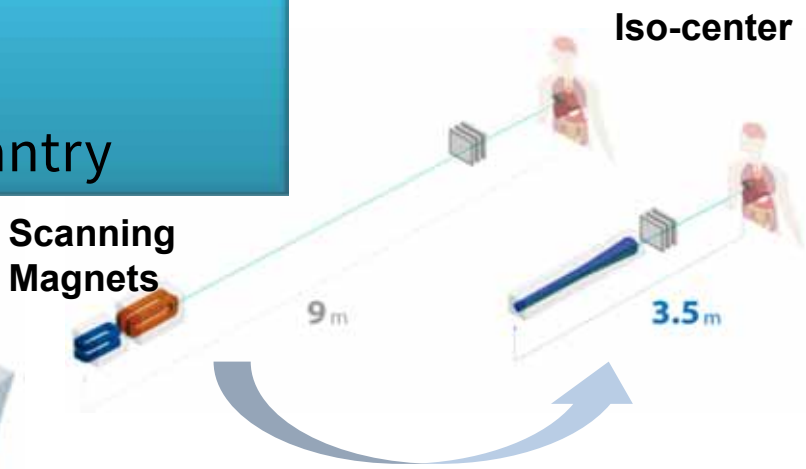
Heavy Ion Cancer Therapy System

Yamagata University Hospital

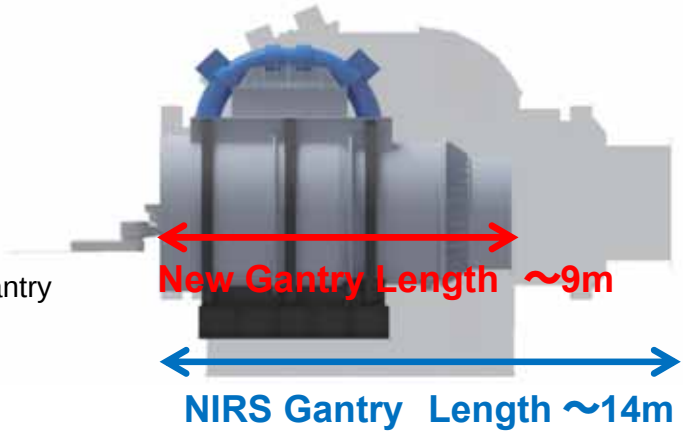
Experience

- Next generation model
- Energy saving
- Downsize irradiation port
- Downsize Superconducting Gantry





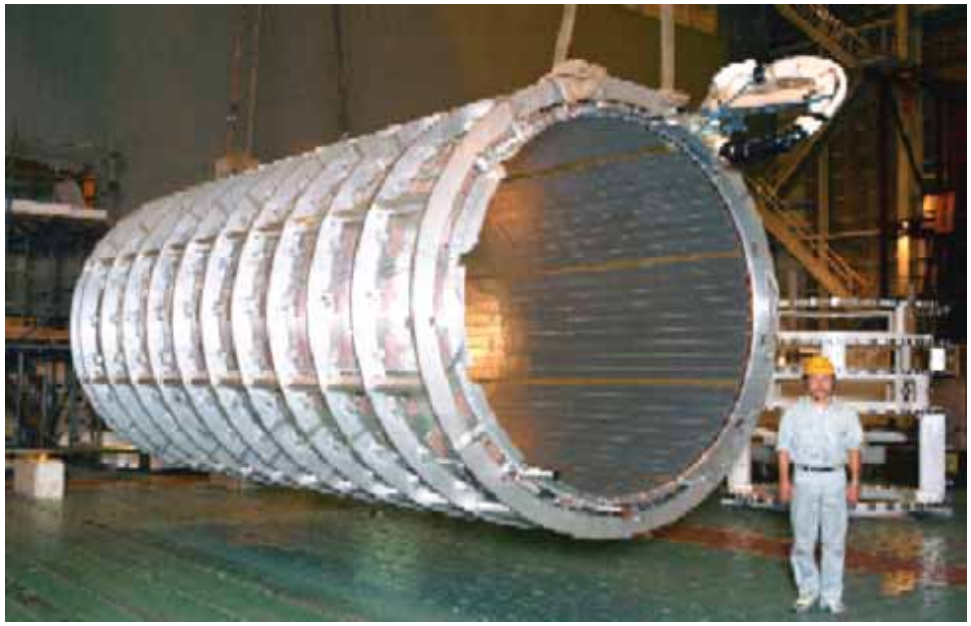
Irradiation port 60%downsize



Superconducting Magnet

ATLAS Central Solenoid Magnet for LHC

Experience



CERN/KEK LHC
operation since 2003

Main Parameter：
- Coil Inner Radius 1229mm
- Coil Length 5300mm
- Conductor 30mm×4.3mm NbTi/Cu/Al

Coil Parameter：
- Operation Current 7600A
- Stored Energy 39MJ
- Central Magnetic Field 2T

Superconducting Magnet

Superconducting Quadrupole Magnet for LHC (MQX-A)

Experience

CERN/KEK LHC

Main Parameter：

- Magnet Length 6.3m
- Coil Inner Radius 35mm
- Magnet Outer Radius 245mm
- Weight 8.3ton

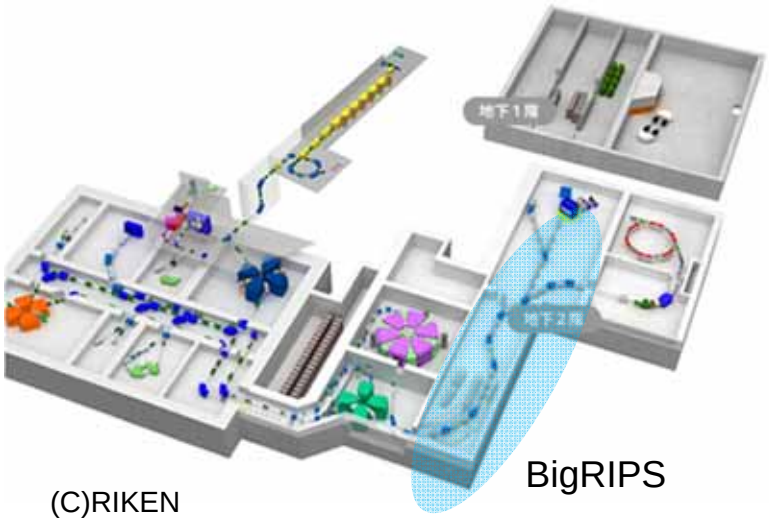
Coil Parameter：

- Nominal Current 8057A
- Stored Energy 2. 8MJ
- Peak Field(Nominal) 9.6T
- Cooling 1.8K LHe

Superconducting Magnet

Superconducting Triplet Q Magnet for RIKEN BigRIPS

Experience



(C)RIKEN

BigRIPS

Main Parameter：

- Type Superferric
- Eff. Length 0.5m/0.8m/0.5m
- Warm Bore Radius 0.14m

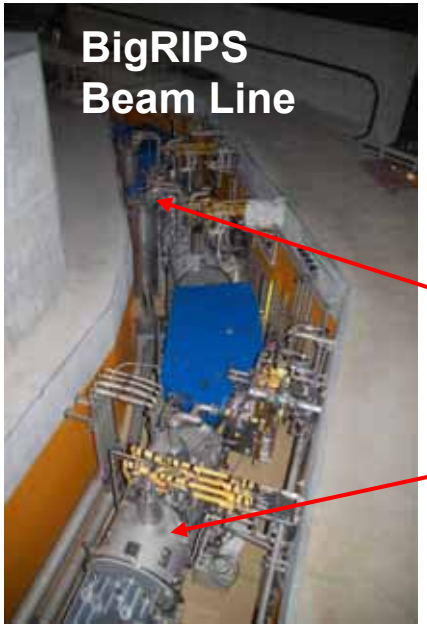
Coil Parameter：

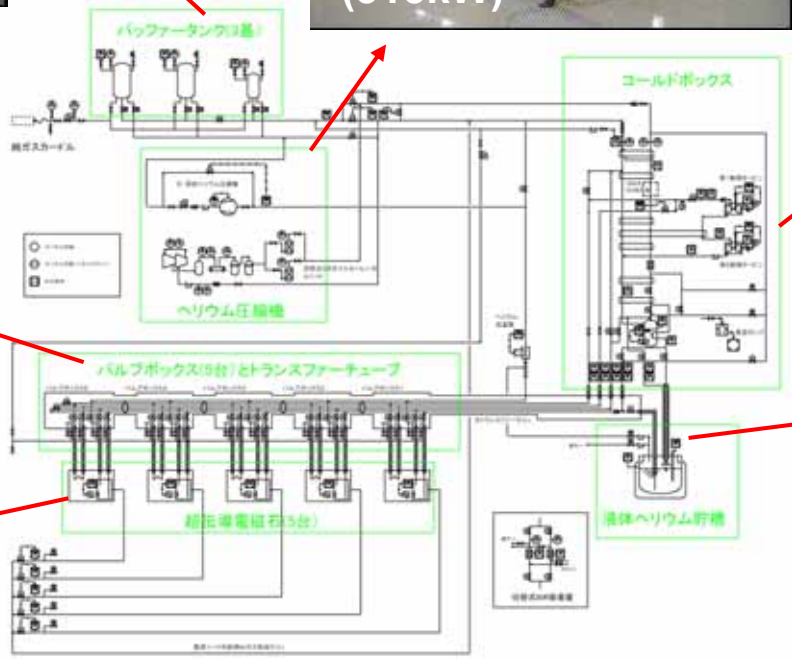
- Nominal Current 135A
- Peak Field(Nominal) 4T
- Winding Race Track
- Cooling Liquid Helium

Superconducting Magnet System

Liquid-helium Cryogenic Plant for RIKEN BigRIPS

Experience





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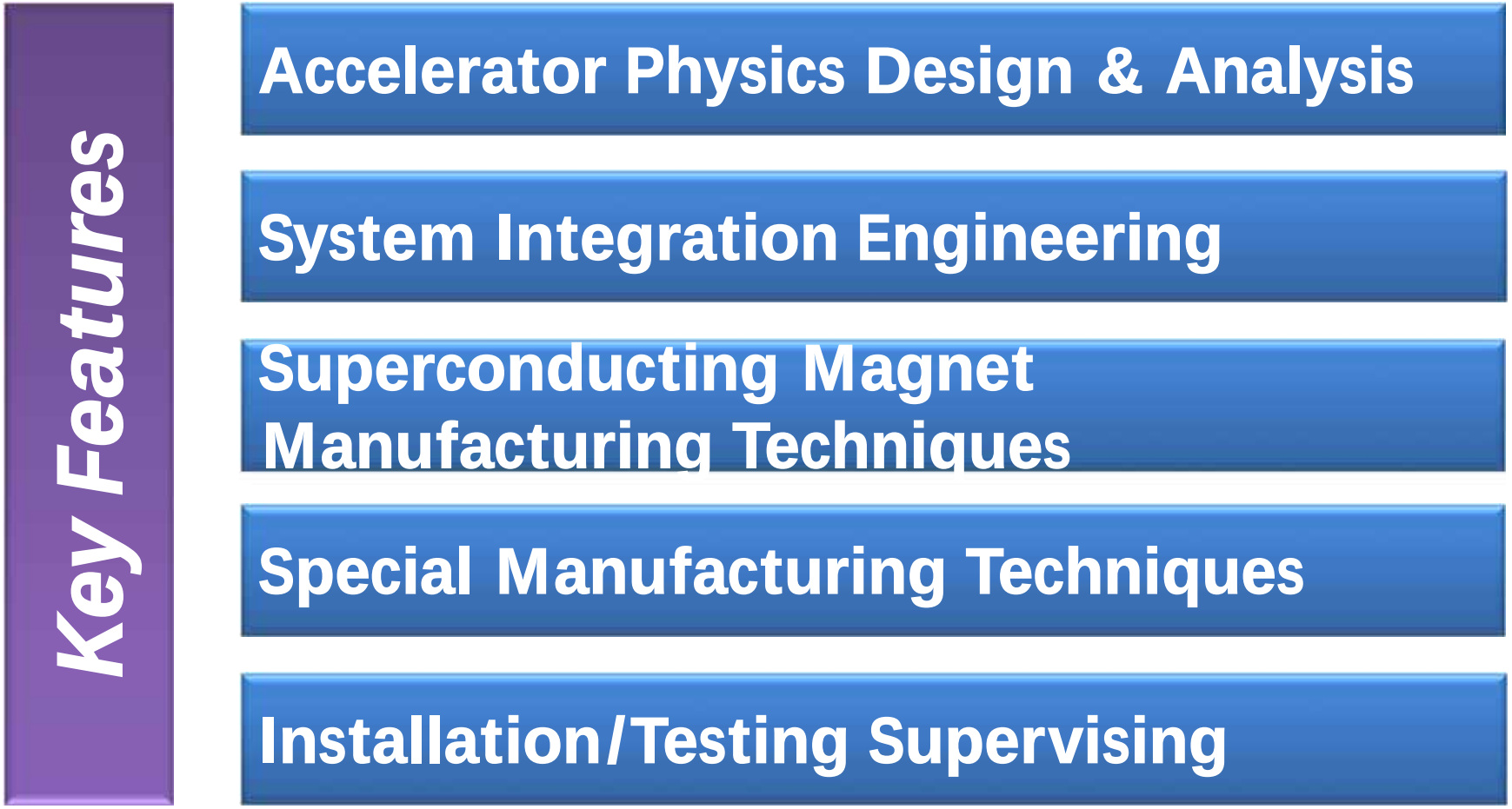
TOSHIBA'S Accelerator Technologies



Accelerator Physics Design & Analysis

Technology

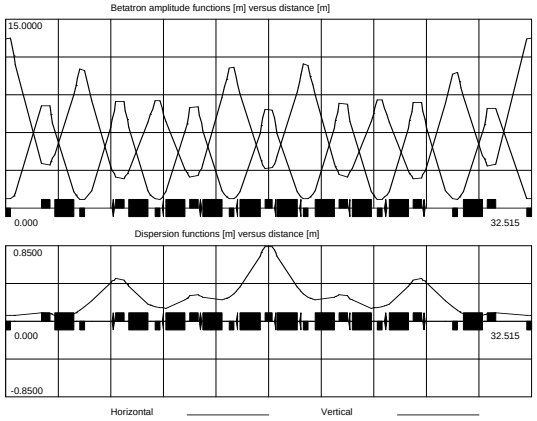
Lattice Design

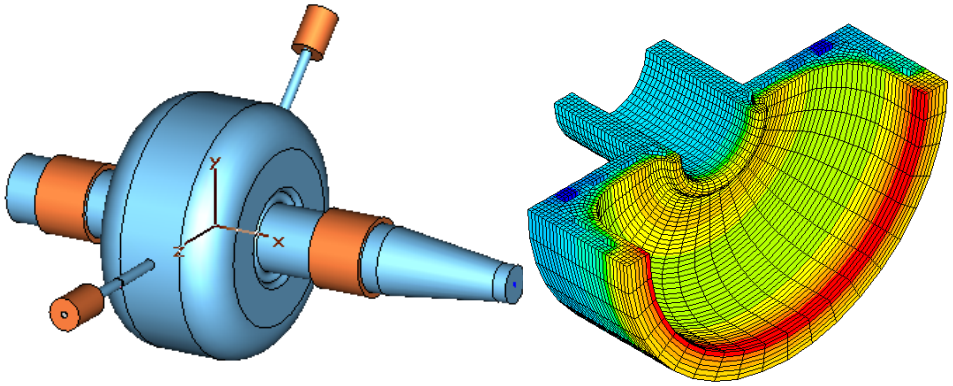
- Toshiba's design capability includes not only manufacturing/testing but basic accelerator planning design such as lattice design and beam physics.

RF/ Mechanical/ Thermal Analysis

- Toshiba's capability includes special analysis technology:

  - 2D/3D Electromagnetic Analysis, Thermal and Deformation Analysis





System Integration Engineering

Technology

Accelerator Physics Design & Analysis

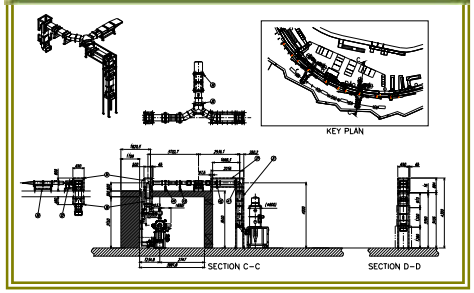
System Design
- Equipment List & Specification
- System Layout
- Single Line Diagram
- Earthing Diagram
- P&ID

Equipment Design
- Magnet & Power Supply
- Monitor System
- Vacuum System
- RF System
- Control System

Installation & Testing
- Installation & Assembling
- Precise Alignment
- Equipment Test
- System Test
- Beam commissioning

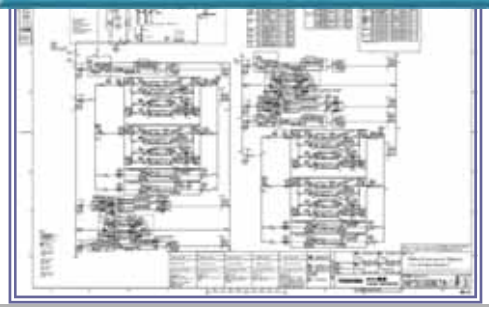
Optimaization

System Layout



Single line Diagram

P&ID



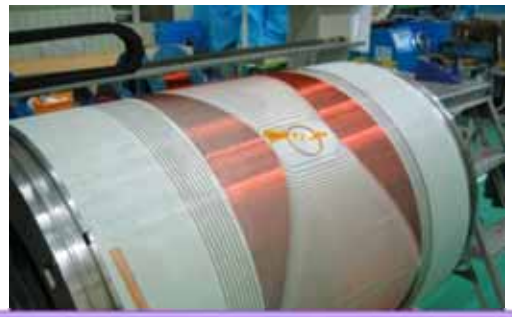
Superconducting Magnet Manufacturing Techniques

Technology

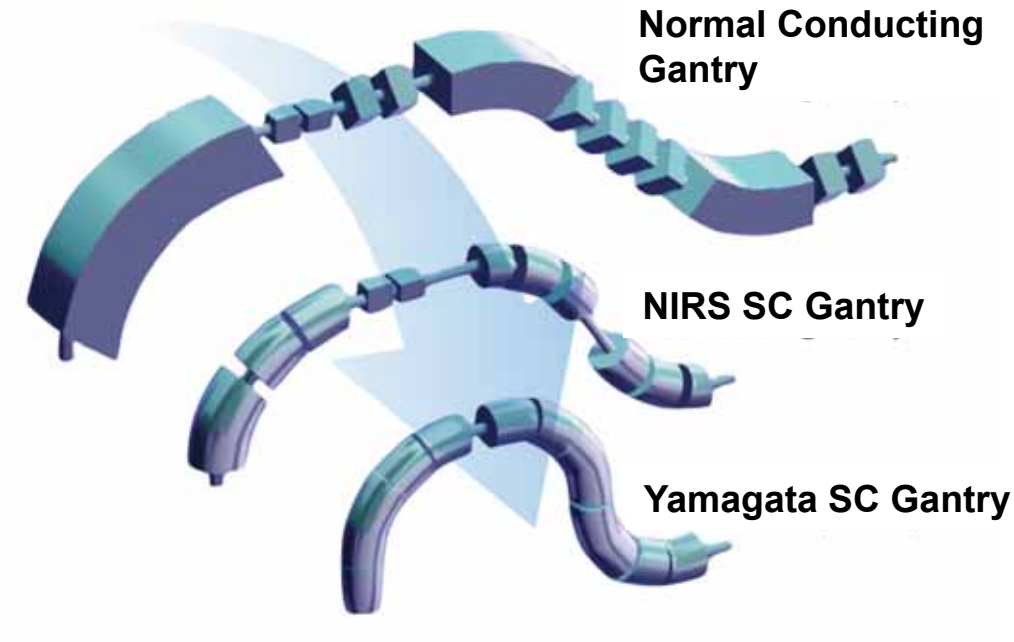
Various Superconducting Magnet manufacturing techniques

- Precise winding: Long length & Precise coil.
- Surface winding: Free shape winding

Precise winding coil



Surface coil winding



Special Techniques

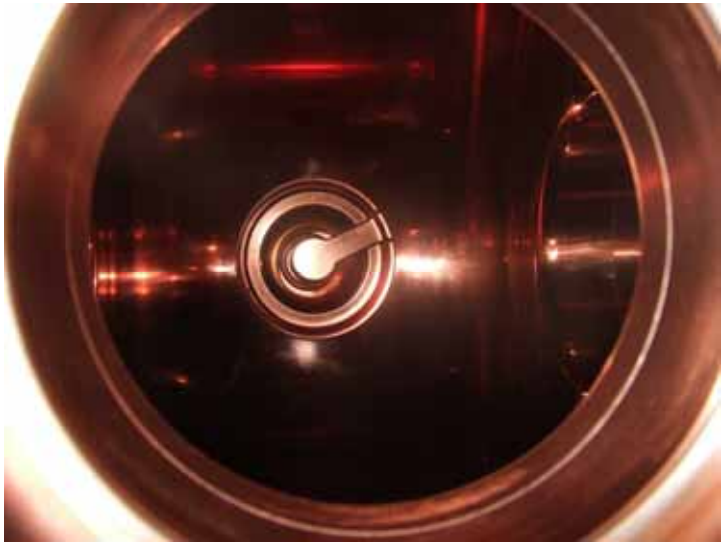
Technology

Precise Machining and Bonding for RF Cavity

・Realize maximization of Q value, minimization of deformation and no water leakage.

Precise Alignment

・Rich experiences of precise alignment for accelerator facilities using Laser Tracker and other optical measuring instruments.

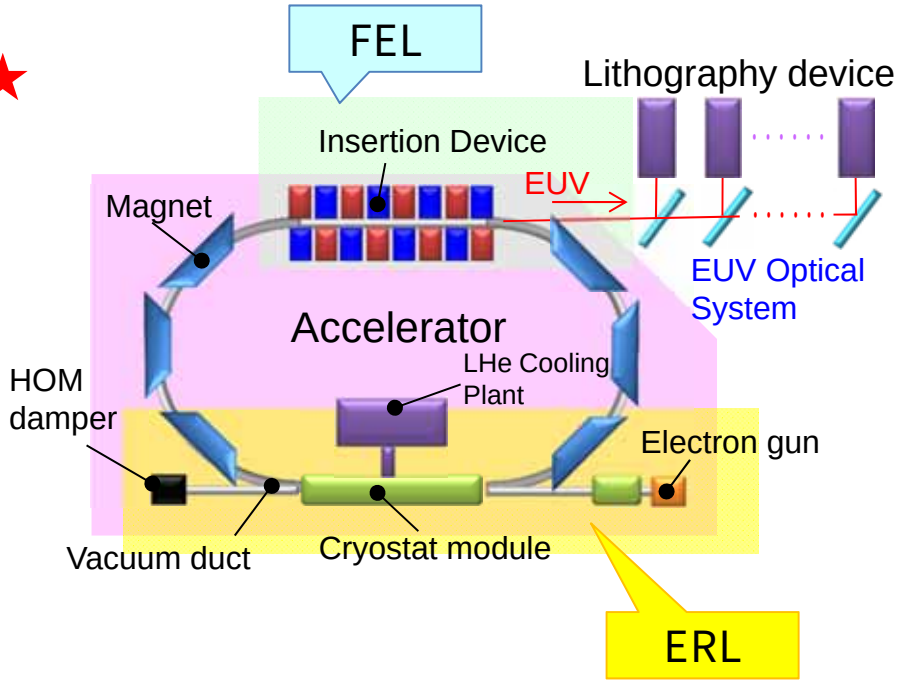


Contents

For Realizing EUV-EFL

■R&D Item：★

- System integration design:★
- Photo cathode Electron gun:★
- Cryostat module
  - Vacuum vessel
  - Superconducting Cavity
  - HOM damper:★
- Insertion Device
- Magnets, Power supply et.al.
- EUV optical system：★
- Exposure system：★



Accelerator Technology + Superconducting Technology Is the Key to the Future

For Realizing EUV-EFL - R&D Activities of Toshiba -

Superconducting Cavity Prototype

ILC specification has been accomplished:

Eacc,max＝35MV/m　@Q0＝8×10^9

HOM Damper Prototype

Completed manufacturing Prototype.

Photo cathode Electron gun

Completed basic design.

Superconducting Cavity

HOM Damper

R&D process is steadily heading towards success

Conclusion

- Toshiba provides the most highly advanced, reliable and stable Accelerator Components and System applying Superconducting Technology, based on our successful experiences.
- Toshiba can
  - contribute from planning stage based on our Accelerator and system engineering capability with Superconducting Technology.
  - provide excellent accelerator components based on our vast design and manufacturing experiences.

We believe that we can contribute to the progress of future industry & science